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Reaching Consensus in Digital Libraries: A Linguistic Approach

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Abstract

Libraries are recently changing their classical role of providing stored information into new virtual communities, which involve large number of users sharing real time information. Despite of those good features, there is still a necessity of developing tools to help users to reach decisions with a high level of consensus in those new virtual environments. In this contribution we present a new consensus reaching tool with linguistic preferences designed to minimize the main problems that this kind of organization presents (low and intermittent participation rates, difficulty of establishing trust relations and so on) while incorporating the benefits that a new digital library offers (rich and diverse knowledge due to a large number of users, real-time communication and so on). The tool incorporates some delegation and feedback mechanisms to improve the speed of the process and its convergence towards a consensual solution.

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Keywords: Group decision making; consensus; linguistic information; digital library

1. Introduction

Libraries form an essential part of academic institutions, enabling and facilitating the exchange and growth of information, knowledge and culture among teachers, students and the general public[1]. In this sense, libraries represent a focal point of academic life and as such serve also a societal purpose of bringing together people around common themes. This purpose is nowadays enhanced and facilitated by the use of technology and, in recent times, by the so-called digital libraries[2,3].

A digital library (DL) is a collection of information that has associated services delivered to user communities using a variety of technologies[2]. In general, DLs are the logical extension of physical libraries in an electronic information society. Such extensions offer new levels of access to broader audiences of users. As the final aim of a DL system is to enable people to access human knowledge at anytime and anywhere, in a friendly multimodal way, by overcoming barriers of distance, language and culture, and by using multiple network-connected devices, it seems reasonable that

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the decisions about important issues in DLs have to be made by their own users. Therefore, we can see this problem from the point of view of a group decision making problem.

Group decision making (GDM) is a situation faced when individuals collectively make a choice from a suitable set of alternatives. This decision is no longer attributable to any single individual who is a member of the group. This is because all the individuals and social group processes such as social influence contribute to the outcome[4,5].

There have been several efforts in the specialized literature to create different models to properly address and solve GDM situations. Some of these proposals have provided interesting results with the help of fuzzy set theory[6], as it is an efficient tool to model and deal with vague or imprecise options, alternatives and opinions of several decision makers[5,7]. However, there are decision situations in which the experts preferences cannot be assessed precisely in a quantitative form but may be in a qualitative one, and thus, the use of a *linguistic approach* is necessary[4,8].

The *linguistic approach* is an approximate technique that represents qualitative aspects as linguistic values by means of *linguistic variables*, that is, variables whose values are not numbers but words or sentences in a natural or artificial language[8].

On the other hand, it is clear that involving a very large number of individuals in a decision process is a difficult task but, with the appearance of new electronic technologies, we are in the beginning of a new stage where traditional decision models may leave some space to a more direct participation of the "webizens".

In fact, Web 2.0 represents a paradigm shift in how people use the Web as nowadays; everyone can actively contribute content on-line. However, the challenge is to develop more sophisticated Web 2.0 applications with better "participation architectures" that allow sharing data to their users, trusting users as co-developers, harnessing collective intelligence, etc.,[9]. They should be able to overcome the inherent problems of the Web 2.0 Communities as[10,11]:

- Large user base.
- Heterogeneity in the users, which present different backgrounds and use different expression domains.
- The low and intermittent participation rates.
- The dynamism of the Web 2.0 frameworks, e.g. the group of users could vary over time.
- Difficulties of establishing trust relations.

Another important mechanism that has been widely used in decision processes where lots of individuals are involved is delegation[12]. In fact, classical democratic systems rely on delegation in order to simplify the decision making processes: as not all the individuals are involved in the decision process (some of them delegate on others), the final decisions are usually achieved faster and in a simpler way. Even when delegation is widely used in many different decision making environments, it is a subject whose implications and utilization is currently under intensive study[13,14].

In this contribution we present a new consensus tool for DLs by assuming fuzzy linguistic preference relations to represent the user preferences. As many traditional consensus approaches, it implements an iterative process in which the members of the DL interact in order to reach a consensual solution on a particular problem. As aforementioned, DLs present several different inherent characteristics that are not present in usual decision making scenarios. Thus, to overcome the difficulties that arise from those special characteristics, the proposed consensus tool implements some different modules that have been designed to tackle them.

To do so, the paper is set as follows. In Section 2 we present our preliminaries, that is, some of the most important characteristics of DLs and of group decision making problems under fuzzy linguistic preference relations. In Section 3 we introduce the new linguistic consensus tool that helps to obtain consensual decisions among DLs users. Section 4 deals with a real world application of the tool. Finally, in Section 5 we point out our concluding remarks.

2. Preliminaries

In this section we present some important information about DLs and Web 2.0, and some generalities on GDM problems.

2.1. Digital libraries and Web 2.0

In the specialized literature we can found some efforts about the use of these new technologies in what it is being called e-democracy [15], e-participation [16], e-Governance [17] and public deliberation [18,19]. In fact, new Web technologies have allowed the creation of many different services where users from all over the world can join, interact and produce new contents and resources. One of the most recent trends, the so called Web 2.0 [20], which comprises a set of different Web development and design techniques, allows the easy communication, information sharing, interaction and collaboration in this new virtual environment. Web 2.0 Communities, that can take different forms as Internet forums, groups of bloggers, social network services and so on, provide a platform in which users can collectively contribute to a Web presence and generate massive content behind their virtual collaboration [9].

The term Web 2.0 [20] was coined to describe the trends and business models that survived the technology sector market crash of the 1990s. He noted that the companies, which had survived the collapse, seemed to have some things in common: they were collaborative in nature, interactive, dynamic, and users created the content in these sites as much as they consumed it. Web 2.0 is essentially a communication hub rather than a web of textual publication. It is a matrix of dialogs, instead of a collection of monologs. It is a user-centered Web in ways it has not been thus far [2,3].

Developing the idea of Web 2.0 in the library context, the concept of DL 2.0 emerges. According to [3], DL 2.0 can be seen as a reaction from librarians to the increasingly relevant developments in information and communications technology (i.e., Web 2.0 and social software) and to an environment that is saturated with information available through more easily accessible channels. This reaction comes in the form of increased openness and trust toward library users, and in the development of new communication channels and services that are in tune with social developments. DL 2.0 has multiple facets reflecting the typical means of user participation that Web 2.0 enables. These facets include blogging, tagging, social bookmarking, social networking, podcasting and so on.

New Web 2.0 technologies have provided a new framework in which virtual communities can be created in order to collaborate, communicate, and share information and resources and so on. This very recent kind of communities allows people from all over the globe to meet other individuals that share some of their interests. Among the different activities that the users of DL 2.0 usually perform we can cite:

- **Generate on-line contents and documents, which is greatly improved with the diversity and knowledge of the involved people.** One of the clearest examples of this kind of collaboration success is Wikipedia [21], where millions of articles have been produced by its web community in dozens of different languages. It is clear that in a massive service as Wikipedia many situations where it is necessary to make decisions about its inner workings and the contents that are being created arise.
- **Provide recommendations about different products and services.** Usual recommender systems are increasing their power and accuracy by exploiting their user bases and the explicit and implicit knowledge that they produce [22]. These kinds of systems represent a quite powerful addition to DL 2.0 systems where decisions have to be made. A clear example of recommender systems success, which exploits its user's community knowledge to provide personalized recommendations, is the Amazon on-line store [23]. In addition, new recommender systems that use the internal structure and organization among the users of social networks are being currently developed.
- **Participate in Discussions and Forums.** Many on-line communities have grown around a web forum or some discussion boards where users share information or discuss about selected topics. In many of these communities some simple group decision making schemes, as referendum or voting systems are usually used. For example, services like PollDaddy [24] allow to create on-line surveys and polls where users can vote about the best alternative to choose for a given decision problem.

Apart from the obvious advantage of meeting new people with similar interests, DL communities present some characteristics that make them different from other more usual kinds of organizations. In the following we discuss some of those characteristics and how they can affect in the particular case of GDM situations:

- **Large user base.** DL communities usually have a large user base [10] (it is easy to find web communities with thousands of users, i.e. the Spanish Open University library). This can be seen from a double perspective. On the one hand, the total knowledge that a large user base implies is usually greater and more diverse than in a small community. This can be seen as a clear advantage: making decisions is usually performed better when there is a rich knowledge on the evaluated subject. On the other hand, managing a large and diverse amount of opinions in order to extract and use that knowledge might be a difficult task: for example, some of the users might not find easy to use typical numerical preference representation formats and thus, linguistic ones should be implemented.

- **Heterogeneous user base.** Not only the user base in DL communities is large, but it is usually heterogeneous. This fact implies that we cannot easily assume that all the individuals may find easy to use the tools that are being developed and introduced in the websites. A clear example is the use of numerical ratings: some users may find difficult to express their preferences about a set of alternatives using numerical ratings and thus, it may be interesting to provide tools which can deal with natural language or linguistic assessments.
- **Low participation and contribution rates.** Although many DL communities have a quite large user base, many of those users do not directly participate in the community activities. Moreover, encouraging them to do so can be difficult[11]. Many of the users of a DL community are mere spectators that make use of the produced resources but they do not (and is not willing to) contribute themselves with additional resources. This can be a serious issue when making decisions if only a small subset of the users contribute to a decision and it does not reflect the overall opinion of the community.
- **Intermittent contributions.** Partially due to the fast communication possibilities and due to a very diverse involvement of the different members, it is a common issue that some of them might not be able to collaborate during a whole decision process, but only in part of it. This phenomenon is well known in web communities: new members are continuously incorporated to the community and existing users leave it or temporarily cease in their contributions.
- **Real time communication.** The technologies that support DL communities allow near real time communication among its members. This fact let us create models that in traditional scenarios would be quite impractical. For example, in a referendum, it is not easy at all to make a second round if there has been a problem in the first one due to the high amount of resources that it requires.
- **Difficulty of establishing trust relations.** As the main communication way, DL communities use electronic devices and, in the majority of the cases, the members of the community do not know each other personally, it might be difficult to trust other members to, for example, delegate votes. This fact implies that it might be necessary to implement control mechanisms to avoid a malicious user taking advantage of others.

2.2. GDM problems under fuzzy linguistic preference relations

A GDM situation consists of a problem to solve, a solution set of possible alternatives, $X = \{x_1, x_2, \ldots, x_n\}$, $(n \geq 2)$, and a group of two or more experts, $E = \{e_1, e_2, \ldots, e_m\}$, $(m \geq 2)$, characterized by their own ideas, attitudes, motivations and knowledge, who express their opinions about the set of alternatives to achieve a common solution.

One of the problems in this field is to find the best way to represent the information. There are situations in which the information cannot be assessed precisely in a quantitative form but may be in a qualitative one. For example, when attempting to qualify phenomena related to human perception, we are often led to use words in natural language instead of numerical values, e.g. when evaluating quality of a football player, terms like "good", "medium" or "bad" can be used.

The ordinal fuzzy linguistic approach[25] is a tool based on the concept of linguistic variable[26,27,28] to deal with qualitative assessments. It is a very useful kind of fuzzy linguistic approach because its use simplifies the processes of computing with words as well as linguistic representation aspects of problems. It has proven its usefulness in many problems, e.g., in decision making, web quality evaluation, information retrieval, recommender systems, political analysis, etc.

It is defined by considering a finite and totally ordered label set $S = \{s_i\}$, $i \in \{0, \ldots, g\}$, in the usual sense, i.e., $s_i \geq s_j$ if $i \geq j$, and with odd cardinality (usually 7 or 9 labels). The midterm represents an assessment of "approximately 0.5", and the rest of the terms are placed symmetrically around it. The semantics of the label set is established from the ordered structure of the label set by considering that each label for the pair (s_i, s_{g-i}) is equally informative [25]. For example, we can use the following set of seven labels to represent linguistic information:

$S = \{s_0 = N, s_1 = VL, s_2 = L, s_3 = M, s_4 = H, s_5 = VH, s_6 = P\}$, where N = Null, VL = Very Low, L = Low, M = Medium, H = High, VH = Very High and P = Perfect.

Using this approach, it is possible to define automatic and symbolic aggregation operators of linguistic information, as for example the LOWA operator[4].

In GDM, there are several methods that can be applied. These methods can be classified along a spectrum, from directive to participatory decision making. The methods that are closer to the directive range imply that the decision is made by a limited or small number of decision makers in the group. On the other hand, the methods that are lower on the spectrum, towards the participatory range, mean that the decision is made by all the parties involved.

In this contribution, we propose to use a consensual decision model composed by two different processes (see Fig. 1)[4,6,7]:

- **Consensus process.** This process refers to how to obtain the maximum degree of agreement among the experts on the solution alternatives[5]. Usually, this process is guided by the figure of a moderator and it is carried out before the selection process. Clearly, the consensus process is an important step in solving GDM problems because it tries to avoid "winners" and "losers". Consensus requires that a majority approve a given course of action, but that the minority agrees to go along with the course of action. In other words, if the minority opposes the course of action, consensus requires that the course of action be modified to remove objectionable features. It is very important because, in any decision process, it is preferable that the experts reach a high degree of consensus on the solution set of alternatives before obtaining the final solution.
- **Selection process.** This process describes how to obtain the solution set of alternatives from the opinions on the alternatives given by the experts. It consists of two phases: aggregation and exploitation. The aggregation phase defines a collective opinion according to the preferences provided by the experts. The exploitation phase transforms the global information about the alternatives into a global ranking.

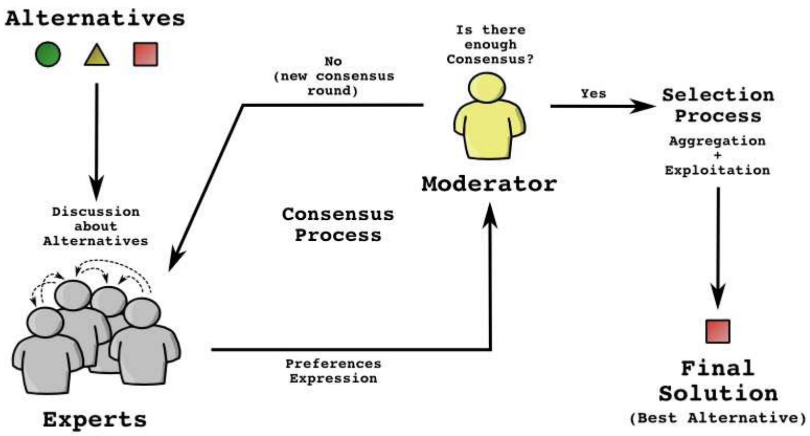

Fig. 1. Classical GDM model.

In such a way, we assume that the experts give their preferences by using Fuzzy Linguistic Preference Relations.

A Fuzzy linguistic Preference Relation (FLPR) P^h given by an expert e_h is a fuzzy set defined on the product set $X \times X$, that is characterized by a linguistic membership function: $\mu P^h : X \times X \rightarrow S$, where the value $\mu P^h(x_i, x_j) = p^h_{ij}$ is interpreted as the linguistic preference degree of the alternative x_i over x_j for the expert e_h.

Moreover, we assume that consensus is a measurable parameter with the highest value corresponding to unanimity and the lowest one to complete disagreement[29]. We can use specific consensus degrees to measure the current level of consensus in the decision process.

Initially, in this consensus model we consider that in any nontrivial GDM problem the experts disagree in their opinions so that decision making has to be viewed as an iterative process composed by several discussion rounds, in which experts are expected to modify their preferences according to the advice given by the moderator.

This means that agreement is obtained only after some rounds of consultation. In each round, we calculate the consensus measures and check the current agreement existing among experts.

Normally, to achieve consensus among the experts, it is necessary to provide the whole group of experts with some advice (feedback information) on how far the group is from consensus, what are the most controversial issues (alternatives), whose preferences are in the highest disagreement with the rest of the group, how their change would influence the consensus degree, and so on. In such a way, the moderator carries out three main tasks: (i) to compute the consensus measures, (ii) to check the level of agreement and (iii) to produce some advice for those experts that should change their minds.

3. A linguistic consensus tool for digital libraries

There have been some attempts to model consensus processes that use new web environments to solve decision problems. For example, in [30] a web based consensus support system for GDM was presented.

The support system was prepared to be incorporated into GDM processes in which the experts would interact using a simple web platform. Therefore, it could not be used to deal with Web 2.0 decision frameworks in which we find large number of individuals with intermittent contributions and low participation rates. Recently, Alonso et al. [31] presented a theoretical model to overcome all these characteristic.

In this section we show a new tool that implements as a basis the theoretical model presented in [31]. It is specifically adapted to deal with DL's features (see Section 2.1) in order to increase the consensus level of the library users when making a decision on a set of alternatives. Some of the properties of the presented tool are:

- It does not require the existence of a moderator. It is the own application who acts as virtual moderator.
- It allows working in highly dynamical environments where participation and contribution rates change.
- It uses linguistic information to model user's preferences and trust relations.
- It allows weighting the contributions of each user according to some degree of expertise (staff, students and professors' opinions could have different weights).
- It implements a feedback module to help experts to change their preferences about the alternatives (the virtual moderator provides recommendations to join the expert's opinions).
- It provides a delegation scheme based on trust that allows minimizing communications and easing the computation of solutions.
- It implements a trust checking procedure to avoid some of the difficulties that the delegation scheme could introduce in the consensus reaching model.

Its operation implies the implementation of several different modules that are applied sequentially in each consensus round (see Fig. 2):

- **Initialization Module.** This module serves as an entry point for the experts that are going to participate in the consensus process. Thus, this module presents the different alternatives $X = \{x1, \ldots, x_n\}$ in the problem to the experts. In Fig 2 we have represented only a small amount of experts, but when applied to DL community the number of users will usually be larger. Once they know the feasible alternatives, each expert $e_h \in E$ is asked to provide a fuzzy linguistic preference relation P^h that represents his/her opinions about the alternatives.
- **Neighbors Computation Module.** For each participating expert e_h a set of neighbors (experts with similar opinions) is computed along with a global current preference relation. This information is presented to the experts. To calculate the neighborhoods we use a distance measure defined in [31]. The global current preference relation is computed by aggregating all the individual FLPRs using the LOWA operator [4].
- **Delegation Module.** This module allows each expert to delegate in other experts (presumably from his computed neighborhood, with similar opinions). Thus, this module creates a kind of trust network that allows experts to leave (temporally or not) the decision process but maintaining part of his influence in the problem.

This delegation mechanism is introduced to soften the intermittent contributions problem (because an expert who cannot continue the resolution process may choose to delegate to other experts instead of just leaving the process) and to decrease the number of preference relations involved in the problem.

- **Feedback Module.** To ease the update of the preferences of the experts that have not delegated (in order to achieve a greater level of consensus) the system will provide several easy to follow feedback rules to the experts. The users will then update their preferences.
- **Consensus Checking Module.** The system will check the consensus status by computing different consensus measures[7]. If the consensus degree is high enough the consensus phase ends and the selection one is applied.
- **Trust Checking Module.** This module is carried out if the consensus measure is not high enough. It is introduced in order to avoid some of the problems that can be derived of the characteristics of DL communities: the difficulties of establishing real trust relations. It is not difficult to imagine a scenario where some experts delegate to another that shares a common point of view on the decision that has to be made and, in a certain consensus round, this expert decides to drastically change his/her preferences, probably not reflecting the opinions of the experts that delegated to him anymore. To avoid this kind of situations this module will compare the last preference relation expressed by expert eh with the last preference relations of the experts that delegated to him/her (direct or indirectly). This comparison is made by applying a distance operator.

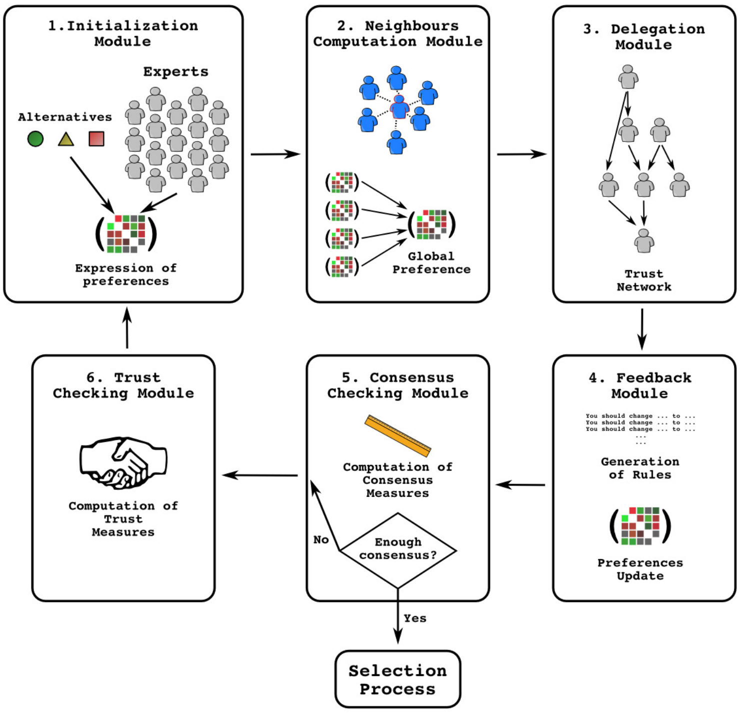

Fig. 2. Scheme of the implemented modules.

4. A real world application: UNED digital library consensus tool

Although the main goal of this contribution is to present a theoretical model which could be adapted to deal with similar GDM problems, in order to test and analyze the presented tool, in this section, we describe the use of the system in a real world DL. Particularly, we present its applicability to one of the most important European DL communities: the Spanish Open University (UNED) academic DL.

With more than 260,000 scholars, UNED is, in terms of the number of students, the largest university of Spain and the second largest in Europe, next to the Open University in the UK. At this moment, the UNED library provides a wide range of 2.0 functionalities. Thus, it is a suitable scenario where our system can be applied perfectly.

In such a vast environment, where thousands of users interact it has been necessary to introduce new tools to avoid conflicts and increase the consensus of the main decisions. As the UNED DL covers a large variety of controversial issues, this kind of tools can help to reach better decisions.

The consensus system proposed in this contribution suits some of those situations. For example, lets imagine a particular conflictive issue as the funding distribution problem. This problem can be modeled like a GDM problem in which the experts are the DL users (students, professors, staff and so on), who has to compare the different alternatives to assign the money. We model the alternatives as the library resources (human resources, space resources, information resources, web resources and so on).

When we apply our tool, we allow choosing a solution of consensus among the alternatives in which the final solution would be a much justified one than if we apply other traditional models as direct and simple voting mechanisms. The mission of incorporating the new tool to an already constructed DL web community as the UNED DL is not a difficult one. In fact, it can be incorporated as a separate tab like polls and forums.

To do so, this tool incorporates two different interfaces, the first one for the library managers and the website administrator and a second one in which the rest of users could express their preferences. The former allows managers to define the problem (creating a description of what is the decision that has to be carried out), to define the available alternatives and other details as the linguistic set that is going to be used. In our case of study we have used the following initial data:

- *Set of alternatives:* {Human Resources (HR), Space Resources (SR), Information Resources (IR), Web Resources (WR)}.
- *Set of linguistic labels:* {Very Low (VL), Low (L), Medium (M), High (H), Very High (VH)}.
- *Minimum consensus level:* 0.8.

On the other hand, the user interface, that allows them to provide their preferences or delegate, is implemented as a client that communicates with a server where all the required processes are carried out. In such a way, the users' task is to compare each pair of resources with the criteria of funding necessity. For example, an evaluation of the pair (HR-SR) of "H" means that HR needs more money than SR, "M" means that HR and SR need the same money, and so on. Therefore, through the initialization module, users are requested to fulfill a form (see Table 1) with their own evaluations:

Table 1. User evaluation.

	HR	SR	IR	WR
HR	-	L	H	M
SR	H	-	VL	L
IR	L	VH	-	M
WR	M	H	M	-

Secondly, the neighbors computation module compares each individual evaluation using a fuzzy distance measure and gives a set of neighborhoods, for example:

- *Neigborhood_1:* $\{1, 53, 96, 275, 356, 584, 789, 866, 1248, 1302, 1788, 1956, 2345, \ldots\}$.
- *Neigborhood_2:* $\{2, 45, 87, 134, 287, 673, 815, 1343, 1886, 2169, 2436, \ldots\}$.
- ...

Then, users have a choice of delegation. They can choose any other user, but the system recommends to do it in one included in their own neighborhood.

Next, except at the first consensus round, the feedback module provides some recommendations to the users, obtained by comparing each individual preference and the collective one (previously computed at the second module), for example:

- *Alert: The current consensus level is not high enough. To improve it, you should change your evaluation on the pair of alternatives (HR-WR) to "H" or "VH" instead of "M".*

At this point, users are allowed to update their preferences. Finally, the system checks the consensus level:

- *Consensus level* = 0.62 (which is lower than the *Minimum Consensus Level*).

As it is still low (as usually before 2 or 3 rounds), a new consensus round have to start. But before to do it, the system carries out the trust checking module and, if it is necessary, sends some warning messages like the next one:

- *"Warning: The user who you delegated in has changed his mind. Please reconsider your delegation decision"*.

Thus, users that receive the warning message are allowed to delegate in other expert or continue in the process themselves. Once the consensus level is high enough, the selection process computes the final ranking and it is presented to the administrator in order to manage the funding distribution. In this case, the ranking is the following: {IR, HR, SR, WR}.

5. Concluding remarks

As conclusions, it is worth noting that although the presented tool manages a series of more or less complex interactions it is based on existing mechanisms (delegation and feedback reinforcement), which are used in real decision making problems. Moreover, the computations of all variables are quite straightforward and thus, the computational complexity of the tools is low. As it happens in real decision making problems, some of the modules of the tool as the delegation or change of preferences steps can slow down the resolution process. However, as those steps do work only during a fixed amount of time for each round this does not represent a noticeable problem.

As the experts are not forced to provide their preferences, to delegate or even to change their opinions, those steps would not interfere with the whole resolution time, even if an expert misses one of the consensus iterations. All the information presented to the experts is provided in a web page that each user can visit at any time in the process. Thus, part of the effort of being informed about the resolution process, his opinion neighbors and the delegation scheme fall into the experts.

To summarize, in this contribution we have presented a new consensus tool that has been specially designed to be applied in DL communities. Particularly, it makes use of existing mechanism that are applied in real decision making situations: it uses fuzzy linguistic preference relations for the expression and management of experts preferences and it has been designed to manage a large users base by means of a delegation scheme. This delegation scheme is based in a particular kind of trust network created from linguistic trust evaluations given by the experts that simplifies the computations and the time needed to obtain the users preferences. Moreover, this delegation scheme also solves the intermittent contribution problem, which is present in almost any on-line community (that is, many of the users will not continuously collaborate but will do it from time to time). The model also incorporates a feedback mechanism to help the experts in changing their preferences in order to quickly obtain a high level of consensus.

In addition, the system allows incorporating new experts to the consensus process, that is, the tool is able to handle some of the dynamic properties that real DL communities have. Finally, the system incorporates a trust check mechanism that allows detecting some abnormal situations in which an expert may try to take advantage of others by drastically changing his opinion and benefiting from the trust that the other experts might have deposited in him in previous consensus rounds.

It has also been shown that this system can be applied in existing DL communities, as the UNED one, to reach consensus in difficult decision making situations.

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